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## AGRICULTURAL PRODUCTIVITY

Julian M. Alston and Philip G. Pardey

One of the most striking and central features of the development of U.S. agriculture has been the increased output per acre, per head of livestock, per farm, and per farm worker, especially during the twentieth century (Bonnen 1986). These are some of the more visible and tangible signs of productivity growth in agriculture arising from investments in the development and adoption of new methods, machines, plant varieties, livestock breeds, and agricultural production know-how.

In the earlier period of expansion of the agricultural land base, production growth came partly from increases in land and labor inputs, as well as from improved technology (Cochrane 1993). During the past 100 years, improved technology has allowed continuing growth in agricultural output from a given or shrinking area of agricultural land, while at the same time using many fewer hours of labor. Labor-saving technology has been critical. Much of the reduction of the agricultural labor force has come about through the consolidation of farms into fewer, more specialized, and larger units. In some instances, especially in intensive livestock and some specialty crops, vertical integration of farming with pre- and post-farm production has been an important element of structural change, facilitated by changes in technologies.

Through these means, U.S. agriculture has been able to supply such an abundance of food and fiber that real, that is, inflation-adjusted, farm-gate prices of food and fiber are much lower than

they were 100 years ago, in spite of the growth in demand for most agricultural products that has accompanied the growth in population, per capita income, and trade (Schultz 1956). Productivity growth is the reason why the Malthusian nightmare, in which subsistence defines the entire economy, has not materialized.

Much of the dramatic transformation of U.S. agriculture over the past 100 years, as well as before that time, can be traced to the adoption of new technologies that allowed more to be produced with less (Griliches 1957; Smith and Roth 1990). To understand fully the implications of technological change requires considering and understanding all of the causes and impacts. Such understanding is elusive because the relationships are complex and ever-changing. A first step is to document those aspects that can be measured and more readily understood.

### The Measurement of Agricultural Input, Output, and Productivity

The data in this section provide a comprehensive picture of U.S. agricultural productivity during the twentieth century, and some partial but useful measures of productivity extending back into the earlier periods. Economists use the word "productivity" in a technical sense with a meaning similar to that found in common usage, only more specific. The general notion is to measure the *quantity* produced, compared with the *quantity* or the *cost* of the inputs used to produce it.

Some *partial* productivity measures express the quantity of a particular output relative to the quantity of a particular input or resource – output or yield per acre, or output per worker (usually per year). Other measures account for more of the inputs. A *total* productivity measure would express total output relative to the total quantity of all of the inputs used in production, but we rarely have all the data needed to measure the totality of inputs and outputs. More often, what is practical to achieve is a *multifactor* productivity (MFP) measure that expresses aggregate output relative to aggregate input – perhaps omitting certain outputs and inputs that are either difficult to measure or not sufficiently covered by available data. For example, the accumulation of highly localized, within-farm information on soil conditions or improved planting, weeding, and harvesting operations has important productivity consequences. Management skill is another type of unmeasured input that accounts for some productivity growth.

These measures or *indexes* of input, output, and productivity necessarily involve aggregating across different commodities, or different qualities of the same commodity, at a given place and point in time; they usually also involve aggregating to some extent over space and time as well. The measures themselves will depend on the decisions made about how to go about this aggregation, which depend to some degree on the availability of data (Griliches 1960, 1963).

As a related matter, the choice of indexing procedure may be important. The so-called *index number problem* arises when distortions in the aggregate quantity (or price) index result from the use of inappropriate price (or quantity) weights in aggregating the quantities (or prices) of individual goods. For instance, the aggregate price index for agricultural output was computed as a Laspeyres index, in which the series of prices of each of the individual commodities making up the index was multiplied by a

weight equal to its individual share of the total value in the base period. This type of index overstates the rise in the cost of living over time because it puts too much weight on the goods that become relatively more expensive over time. Even when this index number problem, associated with the formulation of the index, is avoided or minimized (for example, through the use of Divisia indexes or approximations to Divisia indexes, such as a Fisher–Ideal index), similar problems can arise in aggregating and comparing inputs, outputs, and productivity over space or time. A more complete treatment of these conceptual issues and empirical applications to U.S. agriculture can be found in Acquaye, Alston, and Pardey (2003), AAEA (1980), Ball (1985), Capalbo and Antle (1988), Huffman and Evenson (1993), and Jorgenson and Gollop (1992).

Aggregation bias associated with heterogeneity of inputs and outputs is an issue in developing an accurate sense of the aggregate picture, particularly over long time periods. In aggregating quantities it makes economic sense to use prices as weights, but if the prices and quantities are not perfectly matched (for example, a single national price is used for all states, a single annual price is used for all months or all years, or a single price is used for all grades of a particular output, such as wheat), the picture may be distorted in that changes in quantities of lower- (higher-) value goods will be over- (under-) emphasized (Craig and Pardey 1996; Griliches 1963). For example, over time, the quality of labor and machinery used in agriculture has risen. When we ignore this fact, and just count hours of labor or the number of tractors, our measures overstate the gain in productivity. (Some of the additional output is a result of better inputs; equivalently, a greater quantity of inputs would have been required if input quality had remained constant.)

## Aggregate Input, Output, and Productivity Patterns

### Long-Term Patterns

In 1990, U.S. agriculture produced, in aggregate terms, more than three times the quantity of output in 1910, implying a compound growth rate of 1.61 percent per year. Over the same time period there were substantial shifts in the mixture of output, reflecting both changes in the composition of demand for food and fiber products as incomes have grown and changes on the supply side, reflecting a host of technological innovations (Table Da1063–1081). In 1910 oil crops accounted for just 0.7 percent of the value of production; by 1997 their share had grown to 9.5 percent. Similarly, greenhouse and nursery products accounted for 5.3 percent of the value of output in 1997, well above their 1.8 percent share in 1924. Other crops have declined in importance. The replacement of the horse with the tractor, especially during the first half of the twentieth century, accounts for a significant shift to reduce production of oats (used to feed horses) and to increase both the production of other crops and the cattle herd.

The 1.61 percent per year increase in output over 1910–1990 was achieved with only a 0.06 percent per year increase in the total quantity of inputs, and, comparing those two figures, agricultural productivity grew by 1.55 percent per year (Table Da1117–1122). The comparatively small change in aggregate input use hides a good deal of variation across different categories of inputs, even for a national index. In 1910, labor accounted for 29 percent of the

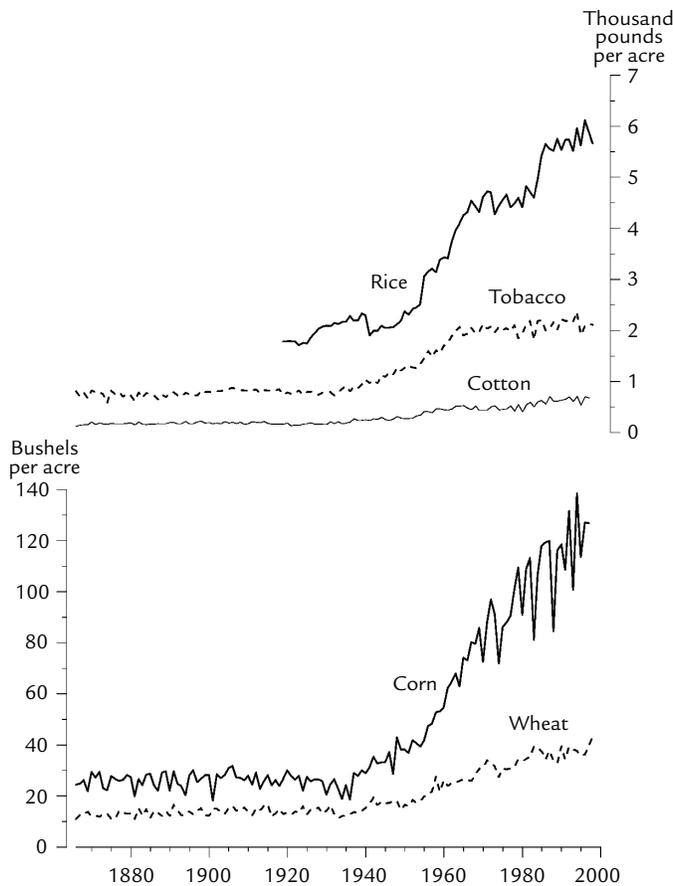
total cost of inputs, but by 1997, the labor input accounted for only 11.9 percent of total input costs (Table Da1082–1094). As a share of total input costs, energy grew rapidly from 1910 to 1932 and continued to grow gradually thereafter. Fertilizer, lime, and pesticide expenses have generally accounted for between 4.6 and 13.8 percent of total input costs. Beginning in 1950, purchased intermediate inputs grew from 14.5 percent of input costs to 18.7 percent in 1997, with a general decline in inputs purchased from farm origin.

These measured output and especially input trends can be misleading, because important changes in quality have not been taken into account in the measures. Simply counting machines does not capture the fact that machines are much more efficient than they were fifty or even five years ago. Similarly, the composition of the agricultural labor force in agriculture has changed to include more experienced and better educated farmers; hence “hours of work” in agriculture means something quite different today than it did in 1910 (Acquaye, Alston, and Pardey 2003). Nevertheless, labor-saving machinery represented an important element in the overall growth in farm productivity. Important innovations in cropping were introduced when tractors replaced horses and self-propelled combines replaced tractor-drawn combines. In earlier periods, of course, the mechanical reaper and binder replaced the sickle and manual shocking.

Much of the farm mechanization for cereal crops started in the 1800s, with important innovations continuing throughout the 1900s, especially in the first half of the century. In the cotton industry, mechanized picking systems did not appear until after World War II. Innovations to mechanize the harvesting of some other crops were much more recent; for example, mechanical harvesters for canning tomatoes and various tree crops were developed after 1960 (Kislev and Peterson 1981). Other important mechanical innovations include various irrigation technologies; technologies used off the farm to transport and process the harvest, including canning, refrigeration, and other food preservation technologies; and other processing technologies such as Eli Whitney’s cotton gin. Electrification was an important development that enabled the adoption of these technologies, in particular in the dairy industry, which was revolutionized by the introduction of milking machines and refrigerated vats.

A significant factor in the aggregate productivity patterns has been the use of biotechnology to improve genetic traits, especially of crops. These changes have led to improved disease resistance; quality improvements such as more uniform grain and fruit, among others; better tolerance for drought, waterlogging, or shorter growing seasons; better adaptation to particular climates or soil conditions; or greater suitability for mechanical harvesting (including more uniform ripening and the ability of the plant or its fruit to withstand mechanical processes) (Olmstead and Rhode 1993). Figure Da-I and Table Da1095–1107 show that per acre yields of crops have grown dramatically, especially during the past fifty years, but with some significant variation among the crops. Genetic improvement is not the only factor, as there have been improvements in chemical fertilizers, irrigation, and weed and pest control, but it is the main factor in many cases, especially for wheat, rice, and corn (Hayami and Ruttan 1970).

Productivity has generally not grown as quickly in the livestock industries as in the cropping industries, partly because genetic improvement has been slower (see Table Da1108–1116). Nevertheless, there have been important innovations in terms of

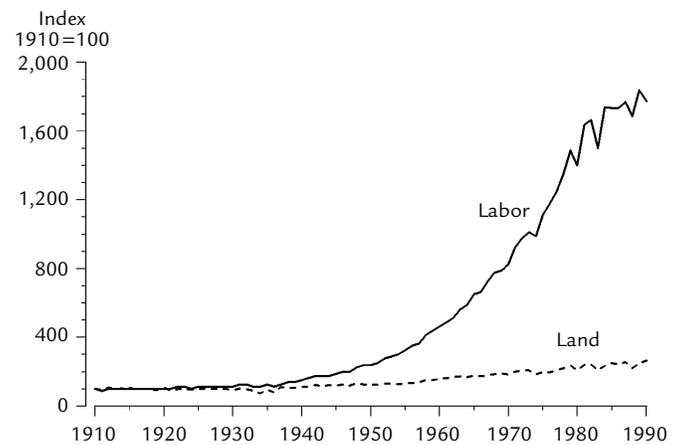


**FIGURE Da-I Average yield per acre for selected crops: 1866-1998**

**Sources**  
Series Da1095-1096 and Da1103-1105.

stocking rates, disease control, greater reproductive efficiency, and improved feed conversion efficiency. Such changes have enabled the development, for instance, of intensive large-scale, highly cost-efficient hog and poultry operations. To do so has meant combining elements of improvements in genetics, animal housing, feed, veterinary knowledge and medicines, and, importantly, livestock husbandry. Many of these changes have been somewhat controversial. People concerned with animal welfare have questioned the intensive livestock systems; people concerned about food safety have questioned the use of growth hormones (for example, rBST used to increase milk yield in dairy cattle was very controversial) and transgenic forms of biotechnology in animals or plants (for example, the introduction of a gene from a soil bacterium, *Bacillus thuringiensis*, into corn and cotton to confer pest resistance, or using similar methods to incorporate herbicide tolerance into soybeans).

Another perspective on productivity can be gleaned by considering the aggregate output per acre or per hour of work, as shown in Figure Da-J. Land productivity more than doubled between 1910 and 1990, but this was dwarfed by the nearly twenty-fold increase in labor productivity over the same period (Table Da1172-1174). This comparison reflects a more than trebling of output against a comparatively unchanging land base and a rapidly declining labor force in agriculture. The increases in land and labor productivity occurred mainly after the 1940s, with a slowing in the growth of



**FIGURE Da-J Indexes of agricultural productivity - labor and land: 1910-1990**

**Sources**  
Land productivity: series Da1172. Labor productivity: 1910-1984, series Da1173; thereafter, series Da1174.

**Documentation**  
The values have been reindexed to 1910 = 100.

both productivity indexes in the 1980s. Increases in the quantities of other inputs, such as fertilizers, herbicides, electricity, fuels, and irrigation, account for some of the growth in output per hour or per acre, but much of the measured growth in productivity reflects changes in technology.

Among the most often cited historical time series of agricultural statistics are the figures on labor requirements for various farming operations. These labor-requirement figures have been updated to the last year before the series were discontinued, and are included here in Table Da1143-1171. Like the measures of labor productivity in Figure Da-J, these labor requirements are partial productivity or factor intensity measures, reflecting the effects of technology and other changes on input-output ratios. For example, in corn production, the figures on the number of hours worked per acre fell from 35.2 in 1910-1914 to 3.1 in 1982-1986, and the number of hours required to produce 100 bushels fell from 135 in 1910-1914 to 3.0 in 1982-1986. The much greater saving in hours per bushel reflects an implied increase in yields from 26.1 bushels per acre in 1910-1914 to 103 in 1982-1986, broadly consistent with the average yields in series Da1096. In turkey production, the figures on the number of hours worked per hundredweight of turkeys fell from 31.4 in 1910-1914 to 0.2 in 1982-1986, a much greater improvement in labor productivity compared with corn, reflecting great changes in input combinations as well as technical improvements.

The labor requirement series were discontinued in 1986 because of concerns over their accuracy and interpretation. It is not known how the figures were derived in the past, but it seems that they were based on expert opinions about best or average practice, and not on any statistical sampling of actual data.<sup>1</sup> The main virtue in these figures is that the series extend back for a long time, into periods for which no alternative data are available on input-output relationships. They might be most useful as indicators of longer-term changes rather than as specific measures of average productivity

<sup>1</sup> See USDA (1987), pp. 4-5, which summarizes Short (1986).

at any particular time, and they illustrate the dramatic changes that have taken place, but they must be used with care.

### Productivity Patterns, 1949–1991

In aggregate terms, in 1991 U.S. agriculture produced more than double the quantity of output produced in 1949. It did this with marginally less aggregate input, causing an index of MFP to grow faster than the rate of growth in output. In annual rate-of-change terms, we estimate that output increased by 1.71 percent per annum over the 1949–1991 period; inputs used in agriculture declined by 0.19 percent, and so measured MFP grew by 1.90 percent per annum. The comparatively small drop in aggregate input use hides a good deal of variation across different categories of inputs, even for a national index.

The quantity of labor used in U.S. agriculture in 1991 was only 40 percent of the labor used in 1949, an average annual rate of decline of 2.2 percent. Labor quality has changed, too. In 1949, 72 percent of the hours worked by farm operators could be attributed to operators with no more than eight years of schooling. In 1991, operators with this level of educational attainment accounted for only 12 percent of total operator hours. In 1949, less than 5 percent of total operator hours were attributable to individuals with any college-level education, but this share increased to 37 percent in 1991.

The amount of land devoted to agriculture also declined. At the national level, land use is reduced from 0.47 percent to 0.30 percent per annum when one controls for changes in the quality of land used in agriculture. This is, in part, the result of the doubling of irrigated acres in U.S. agriculture over the period from 1949 to 1991. There was a slow overall growth in the capital services used by agriculture, even after accounting for the substantial quality improvements in machinery. Purchased inputs such as energy, seeds, fertilizers, and agricultural chemicals represent the only rapidly growing category of inputs; U.S. farmers have more than doubled the quantity of such inputs used since 1949.

These national trends are broadly consistent with regional developments but there are some significant differences in productivity growth (Table Da1232–1243), and even greater variation in the growth of inputs and, especially, outputs among states. Although land inputs have generally declined, they have increased in quality-adjusted terms in some of the drier Western and Southern states, reflecting a more rapid increase in higher-quality irrigated cropland in those states. Disaggregation of the labor inputs reveals that the temporal pattern of change is not the same in every part of the United States nor is it particularly uniform over time. The reduction in total hours worked was more dramatic in the Southern states than in the rest of the country. But in the West the quantity of labor used in agriculture actually increased over the 1970s and 1980s against a national trend of decreasing labor use.

## Research and Development

### Policies and Institutions

Over the centuries, much of the innovation in agriculture has been the result of tinkering by farmers and on-farm experimentation – including much breeding and selection of plants and animals and the development of improved methods, practices, tools, and mechan-

ical innovations. Before the modern scientific age, great advances in American agricultural productivity resulted from the efforts of plant prospectors who imported new and improved varieties from foreign lands. Walter Bruling of Mississippi imported a new cotton variety from Mexico in 1806 that would become the mainstay of the early American cotton industry; Agoston Haraszthy helped transform the California wine industry by importing several hundred grape varieties from across Europe, North Africa, and the Middle East in the 1860s. In addition to the efforts of private citizens, the USDA sent its scientists to the far corners of the globe in search of better plant varieties. These efforts were particularly fruitful in introducing varieties of wheat and other crops suitable for the conditions on the Great Plains (Alston 2002; Pardey, Alston, et al. 1996).

Among the inventors who devised some of the more widely known innovations in U.S. agriculture, we can count Eli Whitney, who patented the cotton gin; Cyrus McCormick, whose mechanical reaper “made bread cheap”; John Deere, whose steel-tipped moldboard plows helped tame the prairies; and Hiram Moore, who built the first combined harvester (combining a reaper and a thresher in one machine). The list of biological innovators is less well known, but the legendary Luther Burbank, who developed scores of new and improved varieties, many of which still bear his name, is representative of thousands of farmer-scientists who by careful selection and, in some cases, hybridization, improved the plant varieties available to American farmers. The private sector has continued to emphasize more patentable inventions. In agriculture, in particular, however, it is difficult for individuals to appropriate fully the returns from their research investments, and it is widely held that some government action is warranted to ensure an adequate investment in research and development (R&D) (Alston and Pardey 1996).

In earlier years, agricultural innovation was encouraged primarily by state and local governments and farmer organizations, through the awarding of prizes and demonstrations of best practice at county fairs and such, but with relatively little organized public research. Until 1862, federal government action to encourage investment in agricultural (and other) research was primarily through patent law enabled by article 1, section 8 of the U.S. Constitution, ratified in 1788. Since 1862, which marked both the establishment of the U.S. Department of Agriculture (USDA) and the passage of the Morrill Land Grant College Act, state and federal governments have become progressively more involved through public investments in agricultural R&D.<sup>2</sup>

The first Commissioner of Agriculture – the noncabinet post that originally directed the USDA – was Isaac Newton, who prior to the department’s establishment had been the Superintendent of Agriculture at the Patent Office, with responsibility for the collection and distribution of seeds for new plant varieties. One of the first acts of the new commissioner was the appointment of a superintendent of the propagating garden, the USDA’s first research facility, on what is now part of the Washington D.C. Mall.

Active intramural USDA research began immediately, with publication of the first research bulletin in 1862, describing the sugar content and suitability for winemaking of several grape varieties.

<sup>2</sup> More details and complete references to the history of these institutions may be found in Alston and Pardey (1996), Alston, Pardey, and Smith (1999), Huffman and Evenson (1993), Kerr (1987), National Research Council, Board on Agriculture (1989, 2003), Rasmussen and Baker (1972), and Weaver (1993).

The early years of the USDA were marked by the slow but steady expansion of the department's internal scientific activities, mostly devoted to "service" work rather than the discovery and development of new knowledge, but leading eventually to the establishment of the Agricultural Research Service (ARS). Under the Progressive Era leadership of James "Tama Jim" Wilson, from 1897 to 1913, the USDA budget grew dramatically (by more than 700 percent during Wilson's tenure), and, by 1904, employment of scientists within the USDA surpassed total employment of scientists in the state agricultural experiment stations (SAESs).

Publicly funded research outside the USDA grew out of the state agricultural experiment stations, developed first in Connecticut by Samuel W. Johnson, based on the prototypes developed in Germany in the 1850s. Following work prior to the Civil War to analyze chemical soil enrichers, Johnson was designated state chemist in 1869, with the formal establishment of the Connecticut Agricultural Experiment Station at Wesleyan University in 1875. At about the same time, experimentation directed to the problems of local farmers was beginning at the state land-grant institutions. USDA funding of external (that is, extramural) research followed the passage in 1887 of the Hatch Experiment Station Act. In the following years, agricultural experiment stations, supported by a mixture of federal, state, and some private funds, and generally located at the various land-grant colleges, opened across the country.

In the early years, extension activities provided local information and technology transfer services to farmers. Eventually the importance and popularity of extension activities led to legislative support, through the Smith-Lever Act of 1914, which created the Cooperative Extension Service and instituted a federal role in extension. During the 1930s, state support for the experiment stations fell sharply. In response, the Bankhead-Jones Act of 1935 provided additional federal support for research as well as extension. Several important features of the earlier Smith-Lever Act carried over to the Bankhead-Jones Act, notably the disbursement of federal funds to the states on a formula basis (20 percent of the funds distributed equally among states, 40 percent based on the state's share of the U.S. rural population, and 40 percent according to its share of U.S. farm population), provided the federal dollars were matched by state funds. In the ensuing years there were further legislative changes, as documented in Tables Da-K and Da-L, but the main elements of combined federal and state funding institutions remained unchanged. Importantly, however, the total amount of funding for public agricultural research and extension, and the sources and disposition of those funds, changed dramatically, especially from the 1960s forward.

### Spending Patterns

Table Da1244–1252 gives a long-term perspective on agricultural R&D spending. In 1889, shortly after the Hatch Act was passed, federal and state spending appropriations totaled \$1,119,136. A little over a century later, in 1997 the public-sector agricultural R&D enterprise had grown to more than \$3 billion, an annual rate of growth of 7.99 percent in nominal terms and 4.39 percent in real terms. Intramural USDA research accounted for an increasing share of the national system, until the late 1930s, after which the SAES share grew to 69 percent of total public spending on agricultural R&D by 1997. Of the funds spent in the SAESs in 1997, 31 percent was from federal sources; 47 percent from state government; and

21 percent from industry, income earned from sales and technology licenses, and various other sources.

Along with the growth in research expenditures, the number of research personnel grew substantially as well. In 1998, the SAESs employed about 7,300 full-time equivalent scientists in addition to the 2,270 researchers employed by the USDA.

In 1915, the first year in which federal funds were made available for cooperative extension between the USDA and various state extension agencies, approximately \$1.5 million of federal funds were combined with \$2.1 million made available from various state and local government sources for a total of \$3.6 million (Table Da1260–1265). This total grew by 7 percent per annum to reach \$1.6 billion by 1999. The public provision of extension services in the United States is essentially a state or local activity. Consequently funds from within-state sources accounted for 74 percent of the total funds for extension, with federal funds accounting for the remaining 26 percent in 1999, much less than their peak share of 62 percent in 1919.

In 1992, the private sector spent \$3.4 billion on in-house agricultural R&D, about 31 percent more than the amount spent by the public sector. Private spending grew by 9.85 percent per annum over the period 1960–1992 (series Da1253), faster than the 8.67 percent per annum for public agricultural R&D spending over the same interval (series Da1244). As a result, for every dollar of publicly conducted research in 1992 the private sector spent \$1.31 compared with just 96 cents in the early 1960s.

The long-term trend of rapidly growing total spending on public agricultural R&D (including extension) slowed in the 1990s. An important element of this was a reduction of federal support for SAES research. This has meant a shift in the balance between the private and public elements in both the funding and the conduct of the research, changes in the mix of research being funded, and changes in other aspects of agricultural science policy as well. Some of these changes have come about as part of a shift in funding for all science, some as a result of a shift of public support generally for agriculture, partly driven by changes in agriculture (Pardey and Beintema 2001). In addition, there have been changes in agricultural science encompassing new molecular biotechnologies and concomitant changes in intellectual property and related institutions.

Among the more striking changes has been the broadening of the scope of intellectual property protection to include inventions involving living things. In the United States, the first steps in this direction began with the Plant Patent Act of 1930, which protected asexually reproducing plants, that is, plants such as grape vines, fruit trees, and ornamentals, which are propagated through cuttings and graftings. The patent scope was expanded further in the 1970s and 1980s through the introduction of utility patents for life forms, including asexually and sexually propagated seeds, plants, and tissue culture. Patent protection was complemented by the introduction of the Plant Variety Protection Act in 1970, designed to strengthen intellectual property protection for nonhybrid varieties.

The public investment in agricultural R&D has been credited with much of the strong growth in productivity over the past 100 years, especially the past 50 years. A great many benefit-cost studies have been undertaken to measure the social payoff of the investment. These studies vary in their findings, but generally agree that it has been a highly productive and socially profitable use of U.S. taxpayer funds (Alston, Chan-Kang, et al. 2000).

**TABLE Da-K Major legislation affecting federal funding of research in state agricultural experiment stations and other cooperating institutions: 1862–1996**

1862	<b>Legislation:</b> Act of Congress. <b>Provisions:</b> Introduced a Commissioner of Agriculture and the U.S. Department of Agriculture (USDA) to take over agricultural science functions of the Patent Office.
1862	<b>Legislation:</b> First Morrill Act. <b>Provisions:</b> Each state could establish and maintain at least one college to teach courses related to agriculture and mechanical arts (without excluding other scientific and classical studies, and including military tactics) in order to promote the liberal and practical education of the industrial classes. This provided for the establishment of the land grant system. <b>Funding:</b> Each state was to receive 30,000 acres of land for each Senator and Representative in Congress. States where not enough public land was available were given script to public land in other states; the income from the land was to be used for operating expenses (construction, purchase, repair of buildings excluded).
1887	<b>Legislation:</b> Hatch Act. <b>Provisions:</b> Each state could establish an experiment station to conduct original research or verify experiments on subjects bearing directly to the agricultural industry of the United States. Stations to be established under direction of land-grant colleges, but exceptions were permitted. This provided for the establishment of the state agricultural experiment stations (SAESs). <b>Funding:</b> Each qualifying state was to receive \$15,000 per year.
1890	<b>Legislation:</b> Second Morrill Act. <b>Provisions:</b> First proposed in 1872. Gave direct annual appropriations to each state to further support land-grant colleges. Forbade racial discrimination in admission to colleges receiving the funds and gave rise to the so-called “1890 colleges.” <b>Funding:</b> Congress gave each qualifying state \$15,000 in the first year, increasing by \$1,000 per year for subsequent years until the annual amount reached \$25,000.
1906	<b>Legislation:</b> Adams Act. <b>Provisions:</b> Each state could receive additional federal funding to pay the necessary expenses of conducting original research and experiments. Emphasis on more science; more accountability; coincides with formation of Experiment Station Committee on Organization and Policy (ESCOP). <b>Funding:</b> Each qualifying state could receive a maximum of an additional \$15,000 per year. Each state was entitled to an increase of \$5,000 for the first year and \$2,000 over the previous year’s sum for five subsequent years.
1925	<b>Legislation:</b> Purnell Act. <b>Provisions:</b> Each state could receive additional federal funding for research (a) to establish and maintain a permanent and efficient agricultural industry and (b) to develop and improve the rural home and rural life. Spending on economics, home economics, and sociology was to be given priority. <b>Funding:</b> Each qualifying state could receive a maximum of \$30,000 per year. Each state was entitled to an increase of \$10,000 for the first year and \$5,000 over the previous year’s sum for four subsequent years.
1935	<b>Legislation:</b> Bankhead–Jones Act. <b>Provisions:</b> SAESs and the USDA could receive additional funding for research into basic problems of agriculture; research relating to quality improvement, new and improved methods of production and distribution, and new and extended uses and markets for agricultural commodities; and research relating to conservation, development, and recreational use of land and water. This legislation established formula funding and federal-state matching grants for research. <b>Funding:</b> A maximum of \$5 million per year, with \$3 million to the SAESs. A total increment of \$1 million per year for each of five years. Funds to be distributed to the states on the basis of their proportions of the rural population of the United States, and each state must match federal contribution with nonfederal funding of the SAES.
1946	<b>Legislation:</b> Research and Marketing Act. <b>Provisions:</b> SAESs and the U.S. Department of Agriculture could receive additional funding for marketing and utilization research, and for regional research involving two or more states on a problem of regional significance. The stated goal of Congress was to maintain a balanced farming and industrial economy. This legislation introduced open-ended appropriations for research and linked spending in agricultural research and development to national welfare. <b>Funding:</b> Title I, Section 9: Total SAES funding up by \$2.5 million in 1947 and 1948; \$5 million increase for each of 1949, 1950, and 1951; such additional funds as Congress shall deem necessary for additional years. Allocation among states: 20 percent equally among states; 26 percent by formula according to state shares of U.S. rural population; 26 percent by formula according to shares of U.S. farm population; 25 percent for regional research; 3 percent for federal administration. Title I, Section 10: Increased U.S. Department of Agriculture funding for research. Authorized grants for “new uses” research to rise from \$3 million in 1947 to \$15 million after 1950; funds for cooperative research into farm product utilization to rise from \$1.5 million in 1947 to \$6 million after 1950; reauthorized \$2 million annual Special Research Fund provided for in the Bankhead–Jones Act of 1935. Title II: Authorized an additional \$2.5 million in 1947, increasing to \$20 million per year after 1950, for marketing research, carried out cooperatively with SAESs and other public and private institutions, on a matching grant basis.
1955	<b>Legislation:</b> Amended Hatch Act. <b>Provisions:</b> To conduct research contributing to the maintenance of a permanent and effective agricultural industry in the United States, including research basic to the problems of agriculture in its broadest aspects, and research related to the development and improvement of the rural home and rural life and the maximum contribution of agriculture to the welfare of the consumer. Removed restrictions on using funds for building, but Hatch funds still had to be spent within the year awarded. Retained allocation formulas, matching grant requirements, and “open-ended” appropriations. Congress rejected a proposal to reduce marketing research by 20 percent and insisted that earmarking apply to all increases in appropriations. <b>Funding:</b> Consolidated federal funding for SAESs into two accounts (formula funds and regional research funds). No set annual amounts were established. Allocation was according to the formula from the Research and Marketing Act: 20 percent of each year’s appropriation equally among states; 26 percent by formula according to a state’s share of the U.S. rural population; 26 percent by formula according to a state’s share of the U.S. farm population; 25 percent for cooperative regional research; 3 percent for federal administration.

**TABLE Da-K Major legislation affecting federal funding of research in state agricultural experiment stations and other cooperating institutions: 1862–1996 *Continued***

1962	<p><b>Legislation:</b> McIntire–Stennis Forestry Research Act. <b>Provisions:</b> Made funding available for forestry research to SAESs, land grant colleges, and forestry schools – including reforestation, woodlands and related watershed management, outdoor recreation, wildlife habitats, wood utilization, and such other studies as may be necessary to obtain the fullest and most effective use of forest resources. The Cooperative State Research Service (CSRS), formulated as such in 1963 and previously the Cooperative State Experiment Station Service (CSESS) formed in 1961, to administer appropriations under McIntire–Stennis. <b>Funding:</b> A formula allocated \$10,000 to each state, 40 percent of the remainder according to a state’s share of the nation’s total commercial forest land, 40 percent according to the value of its timber cut annually, and 20 percent according to its contribution of nonfederal forestry research dollars. In both 1964 and 1965, \$1 million was appropriated, 2 percent of CSRS-managed funds (by 1974 this figure had increased to over \$6 million annually, 7 percent of CSRS-managed money, and by 1984 it was up to almost \$13 million or 6 percent of combined federal funding to the states for agricultural research and development).</p>
1965	<p><b>Legislation:</b> Research Facilities Act. <b>Provisions:</b> Earmarked funds to be matched by the states for the construction, acquisition, and remodeling of buildings, laboratories, and other capital facilities. Supported new construction only of facilities for research on hazardous chemicals used in farming. Allowed each station to obligate its annual share over three years for the first time. IR-4 “National Program of Clearances of Chemicals for Minor and Specialty Uses” launched in 1963. Current Research Information System (CRIS) established in the 1960s. <b>Funding:</b> The formula resembled that in the amended Hatch Act: one third equally to each state; one third according to the proportion of rural residents; one third according to the proportion of farm population. Total allocations were \$3.2 million in 1965, \$2 million per year in 1966, 1967, and 1968; none was provided in 1969, and \$1 million in 1970, for the last time.</p>
1965	<p><b>Legislation:</b> Public Law 89-106. <b>Provisions:</b> Established Specific Research Grants program to finance selected projects, to run for a maximum of five years. Later became the Special Grants program. Earmarked funds to address specific problems of constituent concern or multistate problems. National Agricultural Research Advisory Committee (NARAC) established in 1961. Producer-dominated commodity-oriented research councils declined; they were eliminated in 1970. <b>Funding:</b> CSRS would call annually for proposals in areas singled out by Congress for special attention. In 1966, \$1.6 million was offered; in 1967–1970, \$1.7 million per year. \$283,000 per year was allocated to the sixteen “1890 colleges.”</p>
1972	<p><b>Legislation:</b> Rural Development Act. <b>Provisions:</b> SAESs and the Extension Service could receive funds for rural development and small-farm research and extension. In 1971, Congress granted \$75,000 to each of four rural development centers. Recommended that SAESs devote \$3 million of Hatch appropriations to Community Improvement research. <b>Funding:</b> The 1972 Act authorized \$10 million for 1974, \$15 million for 1975, and \$20 million for 1976. Actual expenditures were much less. \$3 million was provided in each of the first three years, split between extension and research, allocated among the SAESs on a basis similar to the Hatch formula except that 10 percent was reserved for interstate projects. Funding continued at \$3 million per year for another four years after the initial authorization expired in 1977.</p>
1977	<p><b>Legislation:</b> National Agricultural Research, Extension and Teaching Policy Act (Title XIV of the Food and Agriculture Act of 1977). <b>Provisions:</b> Continued and strengthened amended Hatch programs and initiated a new U.S. Department of Agriculture Competitive Grants program for plant science and nutrition research, open to all scientists, to be awarded on a competitive basis to private- and public-sector organizations, including SAESs, all colleges and universities, other research organizations, federal agencies, and individuals. Continued the Special Grants program. Dropped the requirement that 20 percent of amended Hatch funds be earmarked for marketing research. Other new earmarked grants also introduced (for example, energy research, animal health). New mechanisms for more formalized research planning, central (federal) direction, and accountability. <b>Funding:</b> Hatch formula funds were strengthened with \$120 million called for in 1978 and increases of \$25 million per year up to \$220 million in 1982. Allocation was basically as by previous arrangements and formulas. The Competitive Grants program authorized additional spending of \$25 million in 1978, \$30 million in 1979, \$35 million in 1980, \$40 million in 1981 and \$50 million in 1982.</p>
1981	<p><b>Legislation:</b> Amendments to Title XIV (National Agricultural Research, Extension and Teaching Policy Act of 1977). <b>Provisions:</b> Primarily extended the 1977 Act for four years. Introduced \$10 million annual rangeland research program and \$7.5 million annual aquaculture research program. Congress effectively promised not to replace, but to supplement, formula funds with competitive grants. Scope of the competitive grants program was expanded with a biotechnology initiative that included animal science. <b>Funding:</b> Same as the 1977 Act. Hatch funds were authorized to rise from \$220 million in 1982 to \$250 million in 1985. Hatch funds were guaranteed at a minimum of 25 percent of U.S. Department of Agriculture expenditures in cooperative programs.</p>
1985	<p><b>Legislation:</b> National Agricultural Research, Extension and Teaching Policy Act (Title XIV of the Food Security Act of 1981). <b>Provisions:</b> Primarily extended the 1981 Act for four years. Added a new subtitle to promote agricultural productivity. Earmarked funds for marketing research were reintroduced (\$10 million per year) along with Trade Development Centers at land-grant universities (on a matching basis). U.S. Department of Agriculture permitted to fund competitive grants for facilities at SAESs. <b>Funding:</b> Same as 1981 Act. Hatch funds were to grow only 4 percent per year, while Competitive Grants were authorized to increase substantially, especially for biotechnology research. Hatch funding of \$270 million in 1986 to increase to \$310 million for 1990. Competitive Grants funding to increase from \$50 million in 1985 to \$70 million in 1986 and subsequent years.</p>

(continued)

**TABLE Da-K Major legislation affecting federal funding of research in state agricultural experiment stations and other cooperating institutions: 1862–1996 *Continued***

1990	<b>Legislation:</b> Food, Agriculture, Conservation and Trade Act of 1990. <b>Provisions:</b> Primarily extended the 1985 Act for four years. Inception of the National Initiative for Research on Agriculture, Food and the Environment, commonly called the National Research Initiative (NRI). Congress specified target shares for several types of grants within the NRI; not less than 30 percent for multidisciplinary research; 20 percent for mission-linked research; 10 percent for strengthening grants. The legislation also directed the U.S. Department of Agriculture to emphasize, where appropriate, research that enhanced agricultural sustainability. In FY 1991 NRI was restructured and expanded to include four program areas: plant systems; animal systems; nutrition, food quality, and health; and natural resources and the environment. Grant programs regarding markets, trade, and policy as well as processing for value added were included in the following year.
1994	<b>Legislation:</b> Public Law 103-354 Federal Crop Insurance Reform and Department of Agriculture Reorganization Act of 1994. <b>Provisions:</b> Merged the Cooperative State Research Service (CSRS) and the Extension Service (ES) into a single agency, the newly created Cooperative State Research, Education and Extension Service (CSREES). National Agricultural Library (NAL) consolidated with the Agricultural Research Service, which, together with CSREES, the Economic Research Service, and the National Academy of Sciences, report to the newly created undersecretary for research, education and economics.
1996	<b>Legislation:</b> Public Law 104-127 Federal Agricultural Improvement and Reform (FAIR) Act of 1996. <b>Provisions:</b> Merged the three U.S. Department of Agriculture advisory boards, the Agricultural Science and Technology Review Board, the Joint Council on Food and Agricultural Sciences, and the National Agricultural Research and Extension Users Advisory Board to form the National Agricultural Research, Extension, Education, and Economics Advisory Board.

**Sources**  
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**TABLE Da-L Major legislation affecting federal funding of cooperative extension: 1914–1996**

1914	<b>Legislation:</b> Smith–Lever Act. <b>Provisions:</b> Created Cooperative Extension Service to aid in diffusing among the people useful and practical information on subjects relating to agriculture and home economics and to encourage its application. <b>Funding:</b> Provided lump sum grants of \$10,000 per state (\$480,000 total) and additional formula funding. Formula funds were allocated on the basis of a state’s share of the U.S. rural population. Formula funding phased in over seven years, maximum of \$4.1 million. The formula money was to be matched by state funds.
1928	<b>Legislation:</b> Capper–Ketcham Act. <b>Provisions:</b> Provided for expansion of Cooperative Extension Service. <b>Funding:</b> An additional lump sum grant of \$20,000 per state (\$980,000 total per year) and an additional \$500,000 starting in 1929 to be allocated by formula. Required one third of added funds to be matched in 1923 and full matching after 1928.
1935	<b>Legislation:</b> Bankhead–Jones Act. <b>Provisions:</b> Provided for expansion of Cooperative Extension Service. <b>Funding:</b> An additional lump sum grant of \$20,000 per state (\$980,000 total per year) and an additional \$8 million to be allocated to states by formula in 1936 and \$1 million additional for each of the next four years. Formula funds to be allocated by state’s share of the U.S. farm population, matching not required.
1945	<b>Legislation:</b> Bankhead–Flannagan Act. <b>Provisions:</b> Further expansion of Extension. <b>Funding:</b> Two percent of the federal appropriation was for federal administration, 4 percent was set aside for the secretary for special need allocation, and 94 percent was distributed by formula according to a state’s share in the U.S. farm population.
1953	<b>Legislation:</b> Amended Smith–Lever Act. <b>Provisions:</b> Consolidated nine existing Acts; provided for appropriations for Federal Extension Staff in the U.S. Department of Agriculture. <b>Funding:</b> Provided that subsequent increases be allocated 4 percent to special need, 48 percent based on a state’s share of the U.S. rural population, and 48 percent based on a state’s share of the U.S. farm population.
1955	<b>Legislation:</b> Smith–Lever Amendment. <b>Provisions:</b> Special program system established. <b>Funding:</b> Provisions added permitting special nonformula funds.
1961	<b>Legislation:</b> Amended Smith–Lever Act. <b>Provisions:</b> Resource and community development extension added. <b>Funding:</b> Provided \$700,000 per year for resource and community development work.
1962	<b>Legislation:</b> Smith–Lever Amendment. <b>Funding:</b> Froze distribution of current federal funds to each state. Subsequent increases to be 4 percent to the Federal Service, and of the remainder, 20 percent in equal proportions to all states, 40 percent according to a state’s share of the U.S. rural population, and 40 percent according to its share of the U.S. farm population. Formula remained essentially the same in 1999.
1965	<b>Legislation:</b> Smith–Lever Amendment. <b>Funding:</b> Section 3(d) used to provide pesticide chemical programs in Appalachia.
1968	<b>Legislation:</b> Smith–Lever Amendment. <b>Funding:</b> Congress shifted all 3(d) special funds back to formula funding except for \$1.6 million for agricultural marketing.

TABLE Da-L Major legislation affecting federal funding of cooperative extension: 1914–1996 *Continued*

1972	<b>Legislation:</b> Federal Rural Development Act. <b>Provisions:</b> Title V authorized work in rural communities in agriculture and nonagriculture fields. <b>Funding:</b> Funds were to be distributed 4 percent for federal administration, 10 percent for multistate work, 20 percent equally distributed among states, and 33 percent according to a state's share of the U.S. rural population and 33 percent according to a state's share of the U.S. farm population.
1977	<b>Legislation:</b> Food and Agriculture Act. <b>Funding:</b> Changed the Rural Development Title V formula of 1972 to 19 percent for farm research programs and 77 percent for small farm extension programs.
1978	<b>Legislation:</b> Passage of the Resource Extension Act. <b>Provisions:</b> Authorized funding for extension forestry and other renewable national resources. <b>Funding:</b> By appropriation.
1981	<b>Legislation:</b> Agriculture and Food Act of 1981. <b>Funding:</b> Rural development extension funds became part of Smith–Lever formula appropriation.
1994	<b>Legislation:</b> Public Law 103-354 Federal Crop Insurance Reform and Department of Agriculture Reorganization Act of 1994. <b>Provisions:</b> Merged the Cooperative State Research Service (CSRS) and the Extension Service (ES) into a single agency, the newly created Cooperative State Research, Education and Extension Service (CSREES). National Agricultural Library (NAL) consolidated with the Agricultural Research Service, which, together with CSREES, the Economic Research Service, and the National Academy of Sciences, report to the newly created undersecretary for research, education, and economics.
1996	<b>Legislation:</b> Public Law 104-127 Federal Agricultural Improvement and Reform (FAIR) Act of 1996. <b>Provisions:</b> Merged the three U.S. Department of Agriculture advisory boards, the Agricultural Science and Technology Review Board, the Joint Council on Food and Agricultural Sciences, and the National Agricultural Research and Extension Users Advisory Board to form the National Agricultural Research, Extension, Education, and Economics Advisory Board.

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